Gaseous Debris Disks around White Dwarfs

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Abstract. This is a short and rather narrative summary of our ongoing efforts in identifying white dwarfs with gaseous debris disks, and developing an understanding of the structure and origin of these disks.

Keywords: white dwarfs – planetary systems – circumstellar matter – accretion disks
PACS: 97.82

A SERENDIPITOUS DISCOVERY

Early in 2006, while inspecting many thousand spectra of white dwarfs from the Sloan Digital Sky Survey (SDSS, York et al. 2000; Adelman-McCarthy et al. 2008; Abazajian et al. 2009) as part of a large project on white dwarfs with low-mass companions (Rebassa-Mansergas et al. 2007), we noticed emission lines of the Ca II *I*-band triplet in the spectrum of SDSS J122859.93+104032.9 (Fig. 1). On closer inspection, these lines exhibited a double-peaked shape that is the hallmark of gas rotating within an accretion disk (Horne and Marsh 1986). In fact, the full width of the lines, and the separation of their double-peaks is very similar to those observed in many cataclysmic variables (CVs), i.e. white dwarfs accreting from a nearby companion star (see e.g. Fig. 1 in Southworth et al. 2006). At optical wavelengths, no trace of a potential companion star to SDSS J1228+1040 is seen, leaving only the possibility of a sub-stellar companion, such as found in a handful of CVs (Littlefair et al. 2006, 2008). The most striking difference to any known CV was, however, the absence of Balmer or He emission lines. Time-resolved follow-up observations obtained on the William Herschel Telescope (WHT) failed to reveal any significant radial velocity variation of the white dwarf on time scales of hours to days, corroborating the hypothesis that SDSS J1228+1040 is a *single* white dwarf with a circumstellar gaseous disk depleted in volatile elements. The detection of photospheric Mg absorption also demonstrated that the white dwarf is accreting from the circumstellar material.

Pondering about the possible origin of the circumstellar disk around SDSS J1228+1040, memories of *two* ApJ Letters published back-to-back, announcing the detection of dusty debris disks around the white dwarf GD 362 flooded back (Becklin et al. 2005; Kilic et al. 2005, see Farihi, this volume, for a review on debris disks around white dwarfs) and the link was established: we had found a white dwarf with a gaseous debris disk, and the dynamics of the double-peaked line profiles unambiguously showed that the material was residing within the tidal disruption radius of the white dwarf (Gänsicke et al. 2006). Subsequent observations with *Spitzer* revealed that SDSS J1228+1040 also exhibits an infrared flux excess, demonstrating the additional presence of a dusty debris disk component (Brinkworth et al. 2009).

AND THEN THERE WERE THREE

The natural consequence of such an exciting discovery was to search for more objects of this kind. Scrutinising Data Release (DR) 5 revealed a second DA white dwarf with Ca II emission lines, SDSS J104341.53+085558.2 (Gänsicke et al. 2007). As in SDSS J1228+1040, we detected photospheric Mg absorption, implying ongoing accretion onto the white dwarf. As part of this study, we obtained *I*-band spectra of WD 1337+705, a well-known metal-polluted DA white dwarf with a similar effective temperature as SDSS J1043+0855 and SDSS J1228+1040, which did, however, not reveal any Ca II emission. Farihi et al. (2009) observed WD 1337+705 with *Spitzer* and did not detect any significant infrared excess, and suggest that the detection of a dusty debris disk requires an accretion rate of $dM/dt \geq 3 \times 10^8 \mathrm{g\,s^{-1}}$. Similarly, the presence of Ca II emission lines appears to correlate with the degree of metal pollution.

A third gaseous debris disk white dwarf was found in DR 6 (Gänsicke et al. 2008). SDSS J084539.17+225728.0 has a helium-dominated (DB) atmosphere, which strongly limits the hydrogen content of the circumstellar disk: because of the strong gravity of white dwarfs, hydrogen will float on top of the atmosphere. The very low hydrogen abundance in SDSS J0845+2257, $\mathrm{H/He} \leq 3 \times 10^{-5}$, implies that the circumstellar material is dramatically depleted in volatile elements with respect to solar abundances, corroborating the "rocky asteroid" origin of the debris disk.

All three white dwarfs with gaseous debris disks have effective temperatures in the range $\sim 18000 - 22000$ K, and masses which are slightly above the mean mass for single white dwarfs, pointing towards ~A-type progenitor stars.

OUTLOOK

At the time of writing these proceedings, we pursue a number of projects that will eventually lead to a better understanding of the structure and origin of these gaseous debris disks. Analysing DR 7, we have identified two more systems, the DB white dwarf SDSS J073842.56+183509.6 (independently found by Dufour et al. 2010 because of its very strong photospheric metal lines – though these authors failed to note the presence of the emission lines) and another DA white dwarf (Fig. 1). The two new additions extend the temperature where gaseous disks exist down to ~ 13500 K. *HST*/COS and UVES spectra of SDSS J1228+1040 and SDSS J0845+2257 have been obtained and will provide detailed insight into the chemical abundances of the circumstellar material. Spectroscopic monitoring of the Ca II emission lines reveals changes in both the morphology of the profiles as well as of the line fluxes, indicating that these debris disks evolve on time scales of years – potentially suggesting that they are the hallmark of recent disruption events that are settling down into a dust-only configuration. Finally, a photoionisation model developed using CLOUDY (Ferland et al. 1998) demonstrates that the observed line fluxes can be understood by heating the top layers of the metal-rich gaseous disks with ultraviolet photons from the white dwarf.

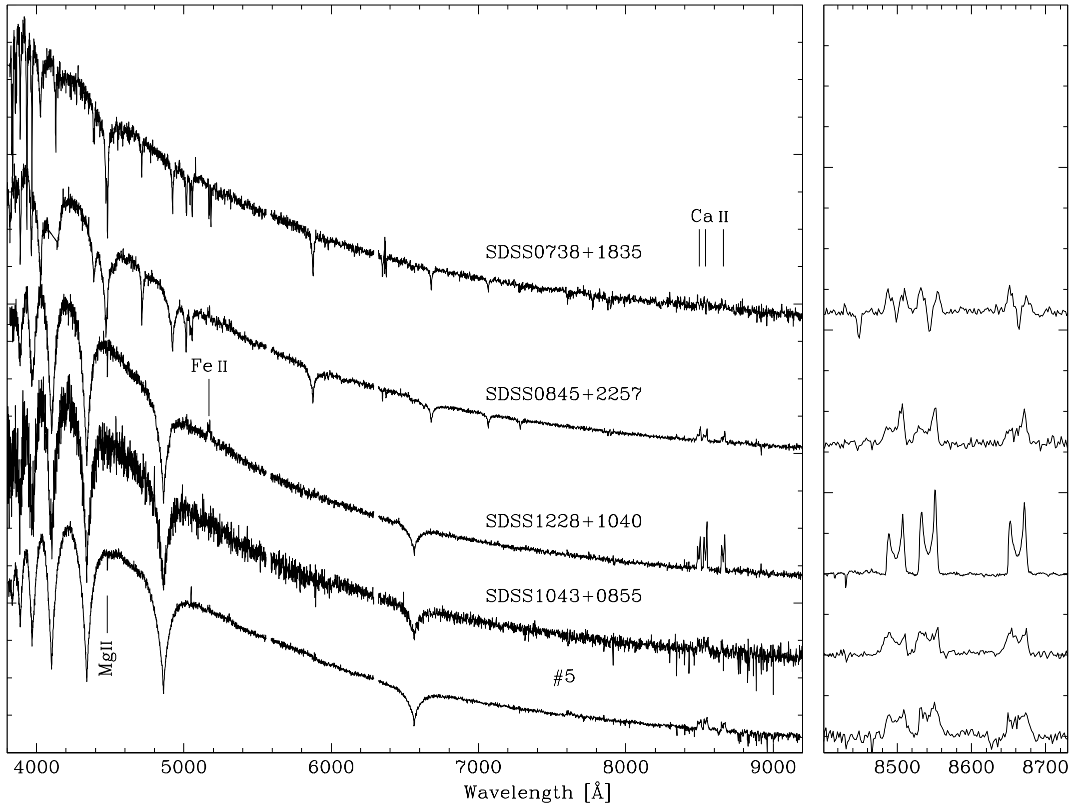

FIGURE 1. SDSS (left) and WHT (right) spectra of the five white dwarfs with gaseous debris disks known so far (from Gänsicke et al. 2006, 2007, 2008, and Gänsicke et al. in prep).

ACKNOWLEDGMENTS

I would like to thank my collaborators on this topic for all their help and input over the past few years: Elmé Breedt, Carolyn Brinkworth, Jay Farihi, Jon Girven, Tim Kinnear, Detlev Koester, Tom Marsh, Stelios Pyrzas, Alberto Rebassa-Mansergas, John Southworth, and Claus Tappert.

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